OHIO RIVER BASIN PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper No. 40, NWS HYDRO-35* and *Technical Paper No. 49*

Eighth Progress Report
1 July 2001 through 30 September 2001

Hydrometeorological Design Studies Center
Hydrology Laboratory

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DISCLAIMER

The data and information presented in this report should be considered as preliminary and are provided only to demonstrate current progress on the various technical tasks associated with this project. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any purpose other than for what it was intended does so at their own risk.

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1. Introduction.

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is updating its precipitation frequency analysis for the Ohio River Basin. Current precipitation frequency studies for the Ohio River Valley are contained in *Technical Paper No. 40* "Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years" (Hershfield 1961), *NWS HYDRO-35* "Five- to 60-minute precipitation frequency for the eastern and central United States" (Frederick et al 1977) and *Technical Paper No. 49* "Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States" (Miller et al 1964). The new study includes collecting data and performing quality control, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

The study will determine annual and seasonal precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. The study will review and process all appropriate rainfall data for the Ohio River Basin study area and use accepted statistical methods. The study results will be published as a Volume of NOAA Atlas 14. They will also be made available on the Internet as web pages with the additional ability to download digital files.

The study area covers 13 states completely and parts of nine additional bordering states (Figure 1). The Susquehanna River and Delaware River Basins are included in the study area. The core and border states, as well as regions used in the analysis, are shown in Figure 1.

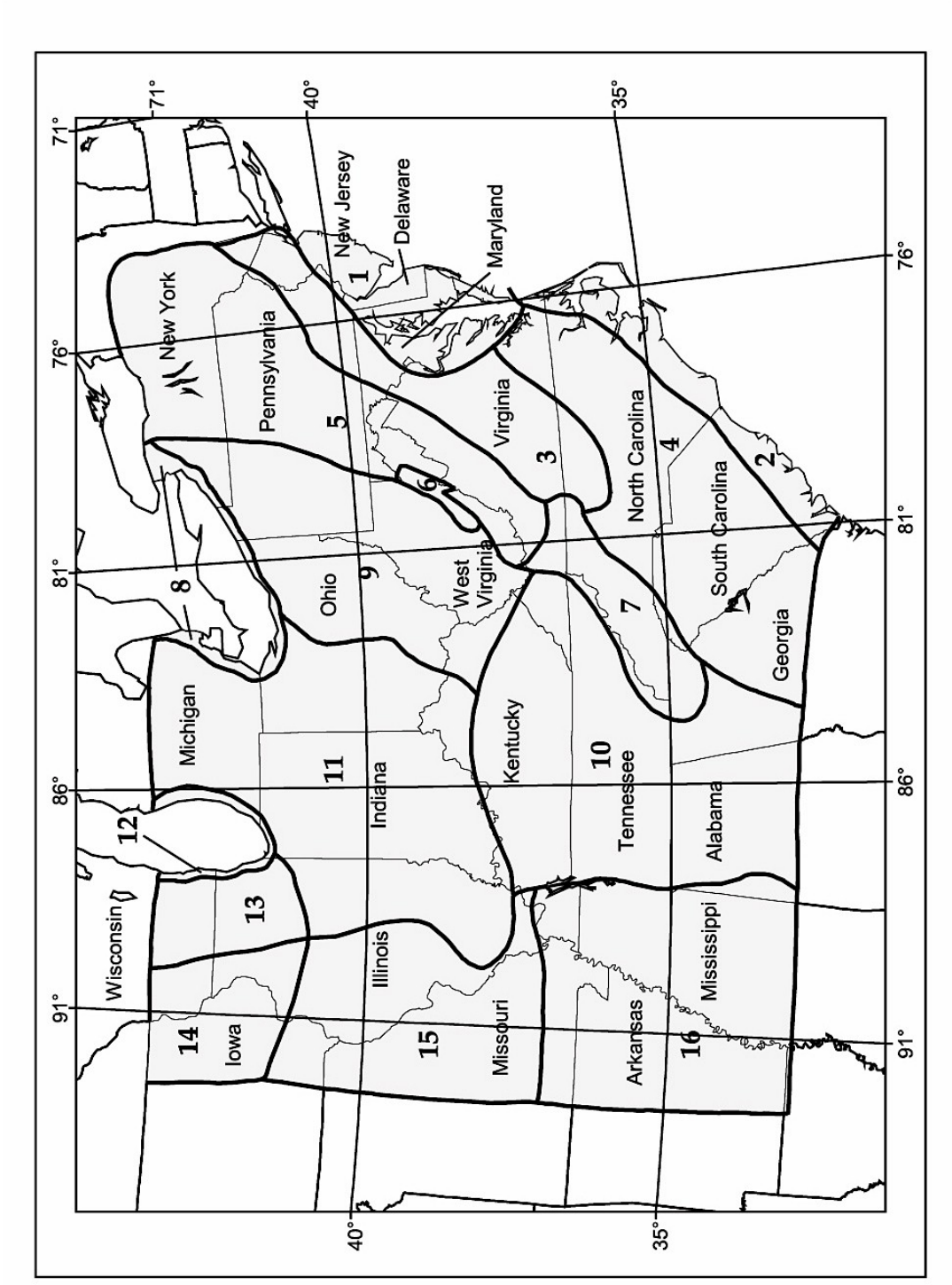

Figure 1. Ohio River Basin Precipitation Frequency study area and region boundaries.

2. Highlights.

Significant progress was made on the technology review initiated in the previous reporting period (Seventh Progress Report for the Ohio River Basin Precipitation Frequency Study, July 2001; Section 5, Issues):

A.) The daily and hourly datasets through December 2000 have been collected and quality controlled. HDSC also included the NCDC 15-minute dataset, which contains roughly 840 stations, in the Ohio River Basin Study.

B.) In an L-moment Applications Working Group, a panel of three independent experts confirmed our current statistical analysis procedures with minor modifications.

C.) Discussions held between HDSC and the Spatial Climate Analysis Center determined that the Parameter-elevation Regressions on Independent Slopes Model (PRISM) technology will be adapted to precipitation frequency data.

Additional information is provided in Section 4.1, Update of Technology Review.

Work on the Internet-based Precipitation Frequency Data Server (PFDS) has continued for the Ohio River Basin Precipitation Frequency Study. In particular, areal calculation of precipitation frequency has been modified to allow user-entered longitude and latitude points to establish the size of the area. An improved web page framework has also been developed. The PFDS will accommodate future studies for the entire United States. Additional information is provided in Section 4.3, Update of Precipitation Frequency Data Server.

3. Status.

3.1 Project Task List.

The following checklist shows each task component and an estimate of the percentage completed per task. Past reports may be referenced for further information.

Ohio River Basin study checklist [estimated percent complete]:

Data Collection, Formatting and Quality Control [95%]:
- Daily
- Hourly
- 15-minute
- N-minute

L-Moment Analysis/Frequency Distribution for 5 minute to 60 days and 2 to 1000 years [90%]:
- Daily
- Hourly
- 15-minute
- N-minute

Algorithm/Data Plot [15%]
- Establish regions from spatial, topographic and meteorological variables
- Run L-moments for regional growth factors to generate dataset
- Create 2yr-24hr precipitation frequency index map using PRISM
- Create ratio maps: 2yr (1-12) hr/2yr 24hr, 2yr (2-60) day/2yr 24hr
  - Plotting
  - Review hand-drawn analysis
  - Perform digitization
  - Rasterization
- Create regional growth factor maps: (5-100) yr (1-12) hr, (5-100) yr 24hr, (5-100) yr (2-60) day

Precipitation Frequency Maps [10%]
- Create frequency maps for 1-hour to 60-day durations at return periods 2 to 1000 years (seasonal and annual maximum) by multiplying index map rasters and using appropriate regional growth factor and ratio map rasters
- Create maps and/or relations for durations smaller than 1 hour (5, 10, 15, 30 minute) using index map and appropriate conversion factors
- Perform internal consistency checks (comparing rasters of sequential duration and frequency)

Data Trend Analysis [50%]

- Analyze linear trends in annual maxima and variance over time
- Analyze shift in means of annual maxima between two time periods (i.e., test the equality of 2 population distribution means)

Seasonal Analysis [50%]

- Create graphs of percentage of precipitation maxima in each month of a year

Temporal Distributions of Extreme Rainfall [0%]

- hourly data assembled by quartile of greatest precipitation amount and converted to cumulative rainfall amounts for each region
- graphs of representative storm-types and seasons

Spatial Relations (Depth-Area-Duration Studies) [0%]

- analyze critical storms to determine depth-area-duration relations
- small-area, short-duration relations
- area-depth curves for areas <500 mi^2 and for >500mi^2
- families of mass curves and area-depth curves as a function of duration and area size
- a smoothed set of curves to distinguish between convective, tropical and non-tropical storms (if appropriate)

Deliverables [5%]

- Write hard copy of Final Report
    - Maps of analyzed results
    - Graphical relations to obtain intermediate values
    - Seasonal variation
    - Depth-area distribution
    - Temporal distribution of rainfall in extreme storms
    - Implement peer and interagency reviews
- Prepare data for web delivery
- Prepare documentation for web delivery
- Publish hard copy of Final Report

3.1.1 Data Collection and Quality Control.

The daily and hourly datasets have been updated through December 2000. Quality control of extreme precipitation values has been performed on both datasets.

HDSC decided to include the NCDC 15-minute dataset in the Ohio River Basin Study. Roughly 840 stations are contained in this dataset.

NCDC has recently provided HDSC with pre-1949 daily data. This data is currently being added to the dataset and quality controlled.

3.1.2 Frequency Distribution Fitting Analyses.

This task evaluates and selects the frequency distribution which provides the best fit for the data. A comprehensive L-moment statistical analysis (Hosking and Wallis 1997) of goodness-of-fit has been done on both daily and hourly data through November 1998 for all durations and all regions to select a best-fit distribution. The statistical analysis included the previously omitted 294 daily data stations.

3.1.3 Mapping Analyses.

HDSC continues to explore the possibility of using spatial interpolation tools such as the Parameter-elevation Regressions on Independent Slopes Model (PRISM). Discussions with the Spatial Climate Analysis Center have determined that, with the establishment of additional criteria, PRISM technology will be adapted to precipitation frequency data.

3.1.4 Trend and Shift Analyses.

Annual maxima will be analyzed for statistical trends and shifts using software developed in-house once the dataset update is complete.

3.1.5 Documentation and Publication.

The Ohio River Basin study results will be available on the HDSC Precipitation Frequency Data Server (PFDS) once mapping is complete and reviewed. The PFDS displays precipitation frequency values and intensity-duration-frequency curves and tables. At present, all states can be selected. Where studies are not yet concluded, information on existing precipitation frequency maps, namely TP40 (Hershfield 1961) and NOAA Atlas 2 (Miller et al 1973), is given. The Server is currently password protected and not publicly available.

4. Progress in this Reporting Period.

4.1 Technology Review.

Significant progress was made on the technology review initiated in the previous reporting period (Seventh Progress Report for the Ohio River Basin Study, July 2001; Section 5, Issues).

4.1.1 Data Collection and Quality Control.

Daily and hourly station data through December 2000 was collected, formatted and added to the existing dataset and will be included in the precipitation frequency calculations. The quality control of extreme precipitation values has been completed on both datasets. The quality control process involved methods such as comparing values with other data sources (e.g., NCDC Monthly Climatological Data), previous and next day amounts, corresponding hourly values and other local stations. Few problematic values were found, and most errors were typographical (e.g., 9 inches listed incorrectly as 90 inches).

NCDC has recently provided HDSC with pre-1949 daily data. This data is currently being added to the dataset and quality controlled.

HDSC has decided to include the NCDC 15-minute dataset in the Ohio River Basin Study. It was initially concluded that part of the 15-minute dataset was unusable because it was hourly data displayed in a 15-minute format. While this issue remains, the vast majority of the dataset is valid 15-minute data that should be beneficial to the Ohio River Basin Study. Roughly 840 stations are contained in this dataset and the 15-minute station locations are shown in Figure 2.

HDSC has a well-developed and efficient set of procedures that have been refined over time for extracting and quality controlling data from the National Climatic Data Center. The procedures and data formats are structured to fit effectively into the end to end processes for producing updated rainfall frequency estimates. We intend to continue using these procedures. HDSC plans to publish the final quality controlled time series used in its analysis.

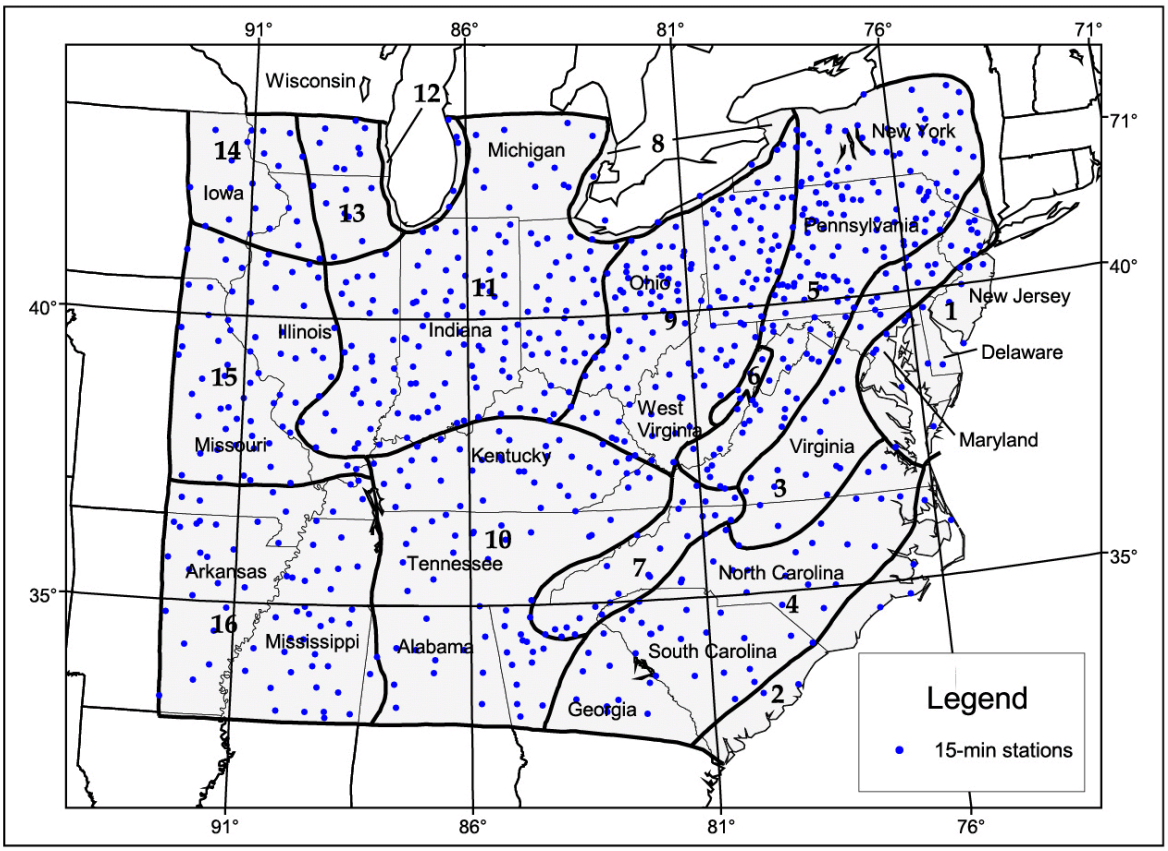

Figure 2. Study area and points marking 15-minute stations.

4.1.2 Statistical Analysis.

Based on recommendations by independent experts during the previous quarter, we held detailed face to face discussions in this quarter with David Goldman (U.S. Army Corps of Engineers), Ned Guttman (NOAA, National Climatic Data Center) and John Hosking (IBM). In the L-moment Applications Working Group, discussions confirmed our general plan to use the statistical procedures described in “Regional frequency analysis: an approach based on L-moments” (Hosking and Wallis 1997). Hosking and Wallis discuss variations in specific areas of their book; HDSC will document and publish those areas where we have made a choice between possible alternatives. We have also decided to adopt the procedures described by Hosking and Wallis for assessing the accuracy of estimated values.

HDSC will use the “unbiased plotting position estimators” unless we can demonstrate that careful use of the “biased plotting position estimators” is more effective. During the next quarter we will use the unbiased estimators while conducting

an assessment of the biased estimators. This assessment should not impact the schedule.

4.1.3 Spatial Interpolation.

HDSC held discussions in Corvallis with Oregon State University's Spatial Climate Analysis Service. It was determined that our concerns about legal issues relating to the use of their PRISM technology mentioned in the previous reporting period can be overcome. While PRISM has been accepted for spatial interpolation of other climatic parameters, it has not been proven in the analysis of rainfall intensity frequency duration estimates. Our technical discussions and more detailed demonstrations of PRISM capabilities have convinced us it is highly likely we will be able to use PRISM for spatial interpolation of the point estimates derived from regional analysis using L-moments. As a result, HDSC has entered detailed discussions with the Spatial Climate Analysis Service to first conduct a final proof test of PRISM technology and then use the technology in our production process.

4.2 Trend and Shift Analysis.

The data through 1998 had been analyzed for any statistical trends or shifts in annual maxima through time. When the data update is complete through December 2000, the analysis will be rerun.

As part of this task, the procedure for extracting annual maxima from the dataset was revised. The criteria now ensure that each year has a sufficient number of monthly maxima to accurately extract an annual maximum.

4.3 Precipitation Frequency Data Server.

The Internet-based Precipitation Frequency Data Server (PFDS), which provides point and areal (up to 400 square miles) precipitation frequency data, is nearly complete. Though initiated for the Semiarid study, the PFDS has been designed to accommodate future studies for the entire United States. The PFDS is capable of generating a color-coded Intensity-Duration Frequency (IDF) curve and data table or color-coded precipitation frequency bar graph on-the-fly. It also provides output for the entire duration list (5-minutes to 10-days) on a single output page. The output graph is a GIF file, which is both printable and savable. For those wishing to save the table data for further processing (i.e., in a spreadsheet program), there is an option to save the data in a comma-delimited format.

The Internet-based Precipitation Frequency Data Server continues to be developed, tested and enhanced. Most importantly, the areal calculation functionality has been modified to be more flexible and accurate. Unlike previous beta versions, the

Precipitation Frequency Data Server now uses a list of user-entered longitude and latitude points to calculate the area size and areal precipitation frequency estimates. Originally it was feared that the areal-calculations would require an unacceptable amount of time to compute, but with the new modifications, the calculation time is very short.

Another important Precipitation Frequency Data Server modification has been the initial development of a new web page framework. The new framework will better accommodate such items as Help, General Information, Feedback, Files for Downloading, Background Information and Contact Information. The new framework will include a Precipitation Frequency Data Server Users Guide as well as an on-line NOAA Atlas 14 Mini-Manual.

5. Issues.

5.1 Retirement of Dr. Lesley Julian.

Dr. Lesley Julian has announced her retirement effective September 30 2001. Dr. Julian was a full time Federal Government employee and we have begun the process of seeking a replacement. Mr. Geoffrey Bonnin is now directly managing the HDSC.

6. Projected Schedule.

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks being worked on in the next quarter are also included in this section.

Data Collection and Quality Control [October 2001]
L-Moment Analysis/Frequency Distribution [October 2001]
Algorithm/Data Plot [November 2001]
Precipitation Frequency Maps [December 2001]
Temporal Distributions of Extreme Rainfall [February 2002]
Spatial Relations (Depth-Area-Duration Studies) [February 2002]
Implement Precipitation Frequency Data Server (PFDS) [February 2002]
Write hard copy of Final Report [March 2002]
Implement review by peers [April 2002]
Publish hard copy of Final Report [June 2002]

6.1 Data Collection and Quality Control.

NCDC has recently provided HDSC with pre-1949 daily data. This data will be added to the dataset and quality controlled. Threshold checks and discordancy checks have been performed on all data except the pre-1949 data as well as the post-1998 data.

6.2 L-Moment Analysis/Frequency Distribution.

A comprehensive L-moment statistical analysis will be done on all datasets through December 2000 for all durations and all regions. The tasks involved with the statistical analysis will take roughly one month for all 16 regions in the Ohio River Basin study area.

6.3 Trend and Shift Analysis.

As part of the data quality control for the Ohio River Basin study, trend and shift analyses were performed on the annual maximum (AM) precipitation data through 1998 (Sixth Progress Report for the Ohio River Basin Precipitation Frequency Study, April 2001; Section II, Task Status). A total of 2755 stations in 22 states were examined. The AM precipitation time series data were found generally free from linear trends and free from shifts in the mean for most stations in the Ohio River Basin at a 90% confidence level.

When the data update is complete through December 2000, the analysis will be rerun. The dataset will be analyzed for any trends or shifts in annual maxima through

time. T-tests will deduce any linear trends in annual maxima or in variance, while t-tests, Mann-Whitney tests and Chi-squared tests will determine any shifts in means of annual maxima. The end products of these tasks are analyses and graphs that will be included in the final document. As part of this effort, the procedure for extracting annual maxima has been refined.

After completion of the trend and shift analysis, data quality control will be performed on stations exhibiting a significantly high linear trend and/or shift in the annual maxima time series data.

6.4 Precipitation Frequency Maps.

A sophisticated cartographic-map making process has been designed using the latest GIS software, ArcView 8.1. During the next few months the review and revision process will result in a final cartographic-quality map template. This map template will then serve as the basis for all future precipitation frequency maps. The maps will be available both online (as ArcInfo ASCII raster, ArcView GIS shapefile, postscript and JPEG files) and in a hardcopy form with the final reports.

6.5 Precipitation Frequency Data Server (PFDS).

Once the data and mapping are finalized, the precipitation frequency estimates for the Ohio River Basin study will be available from the newly developed HDSC web-based Precipitation Frequency Data Server (PFDS). The PFDS will display precipitation frequency values, as well as intensity-duration-frequency (IDF) curves and tables. Eventually, all states will be selectable from the opening U.S. map.

References

Frederick, R.H., V.A. Myers and E.P. Auciello, 1977: Five- to 60-minute precipitation frequency for the eastern and central United States, NOAA Technical Memo. NWS HYDRO-35, Silver Spring, MD, 36 pp.

Hershfield, D.M., 1961: Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years, *Weather Bureau Technical Paper No. 40*, U.S. Weather Bureau. Washington, D.C., 115 pp.

Hosking, J.R.M. and J.R. Wallis, 1997: *Regional frequency analysis, an approach based on L-moments*, Cambridge University Press, 224 pp.

Lin, B. and L.T. Julian, 2001: Trend and shift statistics on annual maximum precipitation in the Ohio River Basin over the last century. Symposium on Precipitation Extremes: Prediction, Impacts, and Responses, 81st AMS annual meeting. Albuquerque, New Mexico.

Miller, J.F., 1964: Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States, *Technical Paper No. 49*, U.S. Weather Bureau and U.S. Department of Agriculture, 29 pp.

Miller, J.F., R.H. Frederick and R.J. Tracy, 1973: Precipitation-frequency atlas of the western United States, *NOAA Atlas 2*, 11 vols., National Weather Service, Silver Spring, MD.